London County Council.

MAIN DRAINAGE OF LONDON.

DESCRIPTIVE ACCOUNT, WITH FOUR ACCOMPANYING PLANS,

BY

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(Presented to the Main Drainage Committee of the London County Council.)

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MAIN DRAINAGE OF LONDON.

GENERAL DESCRIPTION.

The most important feature of modern town drainage, namely, the removal of the house sewage by water in the drains, is of very late introduction.

As the area of the Metropolis was gradually covered with buildings, sewers became necessary; but they were originally intended only to cover or supply the place of natural streams and ditches, and so to carry away the rainfall from the fields, roads, and roofs of the houses.

The subject of drainage in this sense had attracted the attention of the British Legislature at an early period, and as far back, indeed, as 9 Henry III., 6 and 8 Henry VI., 4 Henry VII., and 6 Henry VIII. statutes were made for the purpose of partially regulating the conditions under which works were to be executed. These Acts, however, were of but a local nature; the first measure of a general character was the celebrated "Bill of Sewers," which was passed in the 23rd year of the reign of Henry VIII., 1531, cap. 5.

Subsequently to this Act there were others by which the original Bill of Sewers was amended. These measures were usually applicable to the country in general; but in the Metropolis, owing to the rapid increase of buildings, the legislature was obliged to intervene more frequently.

In 1732, the River Fleet, which previously had been a navigable stream, was covered in, and by Act of Parliament formed into a sewer, below Holborn. The Ranelagh and the King's Scholars' Pond sewers and other important arterial drains, were also closed in about the same period.

About 1810, water-closets were brought into use and were made to discharge into the cesspools. The large addition to the contents of the cesspools made it necessary to introduce overflow drains running into the street sewers. As the buildings increased, and cesspools became more numerous, they were found to be sources of annoyance, discomfort and disease, not only in the house, but by reason of the manner in which the Thames thus became polluted.

As early as 1834, the celebrated painter John Martin, designed a plan in which it was proposed to embank both sides of the River Thames, and to construct *an intercepting sewer* in each embankment, for the purpose of collecting the sewage and conveying it to points in the river below London. The plan was examined by a committee, but was in advance of the time and was not proceeded with.*

Up to about the year 1815, it was penal to discharge sewage, or other offensive matters, into the sewers which were regarded as the legitimate channels for carrying off the surface waters only. Cesspools were considered as the proper receptacles for house drainage. Afterwards it became permissive to drain houses into sewers, and in the year 1847, the first Act was obtained making it compulsory.

Prior to the year 1847, the sewers were under the management of eight distinct commissions, viz., the City, Westminster, Holborn and Finsbury, Tower Hamlets, Poplar and Blackwall, Surrey and Kent, Greenwich, and St. Katherine's Commissions of Sewers. These were independent bodies; each appointed its own officers, and carried out its own drainage works, frequently regardless of the effect thereby produced upon the neighbouring districts, through which the sewage flowed.

Metropolitan Commission of Sewers.

In November, 1847, these eight commissions of sewers were superseded by one commission, termed "The Metropolitan Commission of Sewers," whose members were nominated by the Government. This and subsequent commissions directed their energies mainly to the question of the kind of sewers to be adopted, and to the abolition of cesspools. The result was that, within a period of about six years, thirty thousand cesspools were abolished, and all house and street refuse was turned into the river.†

In 1849, the Thames was becoming full of sewage, and as several of the Water Companies then obtained their supply from the river at or near London, the public press began to agitate for a remedy for this rapidly increasing evil.

Metropolitan Board of Works.

Five more Metropolitan commissions of sewers were formed, viz., two in 1849, one in 1851, one in 1852, and one in 1854. The sixth and last commission was superseded by the Metropolitan Board of Works in 1856 under the powers of the Metropolis Management Act of 1855.

In 1856, the Metropolitan Board of Works, instructed their chief engineer, the late Sir Joseph Bazalgette, to report as to the plans necessary for the complete interception of the sewage of the Metropolis, so as to discharge it into the river below London, instead of into the Thames within the boundaries of the Metropolis. Up to that time the London main sewers drained into the Thames, and most of them, passing under low ground before they reached the river, discharged their contents into the Thames, at or about the level of low water. Under this system there was no free outlet for the discharge of the sewage into the Thames, except at or about the time of low water, and as the tide rose the sewer outlets were closed, and the sewage flowing from the high ground was ponded back in the main sewers. It therefore resulted that the sewage in the low-lying portions of the sewers remained stagnant for long periods. During that time the heavier ingredients were deposited and from day to day accumulated in the sewers. In times of heavy and long-continued rain, and more particularly when such occurred at the time of high water in the river, the closed sewers were unable to store the increased volume of sewage, which then rose through the house drains and flooded the basements of the houses. Owing to the fact that the sewers began to discharge a short time before low water, and continued to discharge a short time after low water, the sewage was carried by the rising tide up the river and was brought back to London by the following ebb tide, there to mix with each day's fresh discharge of sewage, the progress of many days' accumulation towards the sea being almost imperceptible.

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* For the information in the preceding paragraphs I am indebted to the First Report of the Royal Commission on Metropolitan Sewage Discharge, 1884.

† For notes on the sanitary condition of the metropolis prior to the inauguration of the main drainage system see last report of the Metropolitan Board of Works, 1889.

Main features of sewage scheme adopted in 1856

The main feature of the scheme which was adopted in 1856, and carried out between that time and 1874, was the construction of intercepting sewers parallel to the river, with which the main sewers which previously delivered the sewage into the river were connected. These intercepting sewers were carried to Barking on the north side of the river, and to Crossness on the south side of the river. On the north side of the river there were three intercepting sewers, the low-level, the middle-level (with the Piccadilly branch), and the high-level, while on the south side there were the low-level sewer (including the Bermondsey branch), the high-level sewer and the Effra branch sewer. On the north side the high-level and middle-level sewers met at Old Ford, and a little further eastward were joined at Abbey Mills, Stratford, by the low-level sewer. From Old Ford to Barking the sewers are above ground and are enclosed in an embankment and are called the Northern Outfall. On the south side of the river there was only one outfall sewer, which extended from Deptford to Crossness, and was called the Southern Outfall.

It will be seen, therefore, that under the control of the Board, there were three different kinds of sewers, namely, the *main sewers* at right angles to the river, the *intercepting sewers* parallel to the river and the *outfall sewers.* In addition to these, there are the *local sewers,* namely, the smaller sewers in most of the streets in London, which deliver into the main sewers, and which are under the control of the municipal borough in which they are situate.

The northern high-level and the middle-level sewers drained to Barking by gravitation, but as the northern low-level sewer passed along the low-lying land close to the Thames, it was impossible to get such gradients as would carry the sewage to Barking by gravitation, and two pumping stations for lifting the sewage were therefore erected, one (the Western pumping station) at Pimlico, and the other (the Abbey Mills pumping station) at Stratford. All the sewage in the low level sewer was delivered by the pumps at Abbey Mills into the northern outfall, and thence went by gravitation to Barking. On the south side of the river, the sewage in the low-level sewer was pumped at Deptford, whereas the sewage in the high-level sewer and Effra branch sewer was carried by gravitation to Crossness. At this latter station all the sewage had to be pumped.

Two most important points which Sir Joseph Bazalgette had to settle when he was designing the main drainage system were :—

(1) What amount of sewage had to be carried off by the sewers.
(2) What amount of rainfall should be provided for in the sewers.

Taking the mean of the official figures in the census of 1851 and of 1861, which would give the probable population of London at the time Sir Joseph Bazalgette designed his system, we have 1,889,307 persons on the north side of the Thames, and 696,761 on the south side of the Thames, or a total of 2,586,068. The system was, however, designed for the sewage of a larger population than existed at that time, and, as a matter of fact, Sir Joseph Bazalgette arranged for a population of 2,300,000 on the north side of the Thames and 1,150,000 on the south side, or a total of 3,450,000 persons. The next question he had to consider was what amount of sewage per head of population should be provided for, and for this purpose, Sir Joseph took the figure of 5 cubic feet or 31¼ gallons per head per day, which provided for 72,000,000 gallons on the north and 36,000,000 gallons on the south side of the Thames, or a total of 108,000,000 gallons.* The following table gives these figures clearly :—

TABLE No. 1.

	Areas.	Future population anticipated.	Density per acre.	Sewage at 31¼ gallons per head per day.
	Acres.	Persons.	Persons.	Gallons.
North of the Thames	31,896	2,300,000	72·1	72,000,000
South of the Thames	43,546	1,150,000	26·4	36,000,000
TOTALS	75,442	3,450,000	45·7 (mean).	108,000,000

Dry weather flow.

This amount of 108,000,000 gallons was therefore the dry-weather flow provided for in the sewers when they were designed in 1856. The second question which had to be dealt with was the amount of rain water for which provision had to be made, and Sir Joseph Bazalgette decided to provide for a daily flow of 286,000,000 gallons of rainfall, a quantity rather more than two and a half times the flow of sewage provided for. It must be remembered that in 1856 a very large proportion of South London was not built over, and consequently the rainfall from these districts would reach the sewers at a comparatively slow rate, and also a great deal would be evaporated from the ground before reaching the sewers. The figure of 286,000,000 gallons was made up of 178,000,000 gallons on the north side of the river, which represents about $\frac{1}{4}$ inch of rain equally distributed during the 24 hours, and 108,000,000 gallons on the south side of the river, which means a little over $\frac{1}{10}$ inch of rain per day over that area. The total quantities provided for both sewage and rainfall are shown in the following table:—

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* Minutes of Proceedings, Institute of Civil Engineers, Vol. xxiv., and Report by Sir A. R. Binnie, April, 1899.

TABLE No. 2.

	Areas.	Sewage per day of 24 hours as in Table No. 1.	Rainfall per day of 24 hours.	Total sewage and rainfall.
	Acres.	Gallons.	Gallons.	Gallons.
North of the Thames	31,896	72,000,000	178,000,000	250,000,000
South of the Thames	43,546	36,000,000	108,000,000	144,000,000
TOTALS	75,442	108,000,000	286,000,000	394,000,000

It will be seen from this that the total sewage and rainfall provided for was 394,000,000 gallons per day. The discharging capacity of the sewers was, however, made larger than this amount, as it is a well-known fact that, owing to the fluctuating flow of sewage at different hours of the day, about one-half the total quantity flows off in six hours, and as the figures in the above tables give the flow of sewage spread over the whole 24 hours, provision had to be made and was made for practically double the amount of sewage given in these tables.

Rainfall.

When it is remembered that the rainfall in 24 hours often amounts to 1 inch, and that during severe thunderstorms a rate of as much as 1 inch per hour is frequently measured, it will be seen that very little provision was actually made in the sewerage system for dealing with the rainfall. Sir Joseph Bazalgette's scheme for dealing with an amount of rainfall over and above the small amount provided for in the sewers, was to retain for use during times of heavy rainfall, the old sewers which discharged direct into the Thames, and it was provided that, when the sewage and rainfall in the new intercepting sewers attained a certain height, they should overflow into the old sewers, and thus go direct into the Thames. Overflow weirs were therefore made at the junctions of the intercepting sewers with the old main sewers for this purpose. It will be at once seen that this provision for discharging excessive rainfall into the Thames, by means of the old sewers could not be satisfactory at all times, as it has already been pointed out that these old sewers were blocked by the tide for a considerable time before and after high water, and, therefore, the rainfall could only reach the Thames at some time on each side of low water, unless in any case the old sewers were capable of being put under such a pressure as would overcome the opposing pressure of the tidal head. There is no doubt that Sir Joseph Bazalgette's scheme did, however, relieve floodings to a very great extent, as, in addition to the great capacity of the new sewers and the old main sewers, which acted as reservoirs, there were large reservoirs at Barking and Crossness which stored up the sewage and rainfall during the whole period of the floodtide. As time went on, however, and the population of London increased, and more streets were made, the amounts of sewage and rainfall were very much augmented. This was particularly the case on the south side of the Thames, where the development of land for building purposes was very great, and consequently the volume of sewage flowing down the sonthern main outfall sewer in course of time increased enormously, while the substitution of houses and streets for green fields and arable land, not only swelled the amount of the rain flowing off the land into the sewers, but also caused it to reach the sewers much more quickly. The same thing happened on the north side of the Thames, but not quite to the same extent.

The object of carrying the sewage of London to Barking and Crossness, was obviously to prevent its discharge into the river within the boundaries of the Metropolis. These two places are respectively 11 and 13 miles below London Bridge by the river.

Reservoirs were made at both outfalls so as to avoid sending the sewage into the Thames on the flowing tide. These reservoirs were sufficient to contain all sewage which came to the outfalls during a period of about six hours, and the sewage was only discharged into the Thames on the ebb tide. There are clearly two objections to discharging sewage into a river, viz., pollution of the river, and the liability that some of the matters suspended in the sewage may be deposited in the bed of the river and form banks. The first question, that of pollution, will be dealt with later on, but I refer to the formation of banks at once, as these were much more likely to be formed with the crude sewage, such as was delivered at that time, than with the clarified effluent which is now discharged.

Barking inquiry on the pollution of the River Thames, 1869.

In June and July, 1869, an inquiry was held in London by the late Sir Robert Rawlinson, by order of the Home Secretary, in response to a memorial from the Vicar and inhabitants of Barking, alleging, amongst other things:—

(1) That the river was dangerous to navigation and to the health of the inhabitants of Barking, and towns below London, consequent upon the discharge of sewage through the outfalls.

(2) That a bank had been formed in the channel of the river by sewage mud.

(3) That Barking Creek had been closed to vessels of 250 tons burden.

At that time sewage was discharged into the river from both outfalls without any chemical treatment.

After taking evidence on six days Sir Robert Rawlinson reported :—

(*a*) That the allegations in the memorial had only been partially proven.

(*b*) That the memoralists had not proved any deterioration of health due to the outfall works.

(*c*) That the main channel of the Thames had not been reduced in depth of water by the street detritus contained in the sewage.

(*d*) That Barking Creek had not been closed to vessels of 250 tons burden.

(*e*) That an accumulation of mud had taken place both on the shore of the Thames, and at the mouth of Barking Creek, but from what special cause had not been proven.

Thames Conservancy Mud-bank Inquiry 1879.

The Thames Navigation Act of 1870 provided that the Metropolitan Board of Works should, at their own expense, keep the Thames free from such banks or other obstructions to the navigation as might arise from the flow of sewage at the outfalls. This obligation was, however, subject to arbitration should any question arise between the two authorities. Questions did arise on the initiative of the Thames Conservancy in 1878, when the Conservancy contended that banks had formed in the Thames below the outfalls which were due to the discharge from these outfalls. The Metropolitan Board of Works contended that the banks which had to be cleared in the Thames were in no way due to the flow of sewage at the outfalls, and in accordance with the Act of 1870 an arbitration took place between the late Metropolitan Board of Works and the Thames Conservancy in 1879 on this question. The arbitrators were the late Captain Sir Douglas Galton, on behalf of the Conservators, the late Sir Frederick Bramwell, on behalf of the Metropolitan Board of Works, with Sir C. A. Hartley, appointed by the Board of Trade as umpire. These gentlemen heard evidence submitted to them by 24 witnesses for the Conservators, and 17 witnesses for the Metropolitan Board of Works, including the leading civil engineers and other scientific men of the day, and concluded and determined as follows :—

(1) That the banks in question had not obstructed the navigation further than by making the main channels somewhat more crooked.

(2) That they had arisen from the effect of dredging operations.

(3) That the water in the tidal portion of the Thames contained a considerable amount of suspended matter, derived partly from the basins of the Thames and its tributaries, partly from the washing away of the foreshores of the tidal estuary where unprotected, partly from material brought up from the mouth of the river by the flood tide, partly from sand and mud stirred up in the course of dredging operations, partly from denudation of the river bed, partly from sewers in districts outside the metropolitan area, and partly from the sewers of the Metropolitan Board. The proportion contributed from this latter source was small, as compared with the total amount of suspended matter in the whole volume of tidal water, flowing past the outfalls on every tide.

(4) That the banks were composed of matter which had been held in suspension in the water, and had been derived from the several sources above mentioned. Whilst, therefore, the sewage from the Metropolitan outfalls might have contributed to their contents, the banks could not be said, in the sense of the Act of 1870, to have arisen from the flow of sewage at the outfalls ; and the Metropolitan Board should not be called on to remove, or contribute any portion of the expense of removing them.

It is obvious, therefore, that if in 1878 the formation of these banks in the river, could not be attributed to the discharge of *crude* sewage from the outfalls, still less can the formation of banks at the present time be attributed to the discharge of *effluent** from these works.

Royal Commission, 1882–1884.

The next proceeding of importance was in the year 1882, when, in consequence of complaints made to the Secretary of State by the City Corporation, as sanitary authority of the port of London, and by the inhabitants of Erith, a Royal Commission was appointed "to inquire into and report upon the system under which sewage is discharged into the Thames by the Metropolitan Board of Works ; whether any evil effects result therefrom ; and, in that case, what measures can be applied for remedying or preventing the same." The inquiry by the Commissioners, of whom Lord Bramwell was chairman, occupied altogether about two years, the second and final report having been made on 27th November, 1884. The main conclusions arrived at by the Commissioners, shortly summarised, were :—

That the London sewage ought not to be discharged in its *crude* state into any part of the Thames.

That the solid matter in the sewage should be separated from the liquid by some process of deposition or precipitation ; and should be applied to the raising of low-lying lands, or burnt, or dug into land, or carried away to sea.

That the liquid portion of the sewage remaining after precipitation might, as a temporary measure, be then allowed to pass into the river.

The Commissioners, whilst thinking that by these means much of the evil could be abated, were of opinion that the liquid remaining after precipitation of the solid portion of the sewage, would not be sufficiently free from noxious matters to allow of its being permanently discharged at the present outfalls. They intimated that it would require further purification, and this, they thought, could be best effected by intermittent filtration through the land. If suitable land, in sufficient quantity and at reasonable cost, could not be procured near the outfalls, the Commissioners were of opinion that the sewage liquid, after separation from the solids, should be carried down to a lower point of the river, at least as low as Hole Haven.

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* Throughout this description the term *effluent* is used to describe the sewage after it has been treated with chemicals and clarified by precipitation.

The Board carefully considered the question of intermittent filtration through the soil, but found that the acquisition of sufficient land in the neighbourhood of Barking and Crossness, to enable the vast quantity of London sewage to be effectually filtered through the soil, without nuisance to the inhabitants of the locality, would be attended with almost insurmountable difficulty, and that the cost would be enormous.

Precipitation Works. Barking and Crossness, 1887 and 1888

After the second and final report of the Royal Commission, 1884, the Metropolitan Board of Works determined to construct works for the chemical clarification of the sewage.

The precipitation works at Barking were commenced by the Metropolitan Board in 1887, and completed after the London County Council was constituted in 1889. The precipitation works at Crossness were commenced in 1888, and completed in 1891. The sewage, when it arrives at Barking and Crossness, is subjected to chemical treatment, consisting of the addition to every gallon of crude sewage of about 1 grain of proto-sulphate of iron and 4 grains of lime. The precipitation takes place in long channels.

At the Barking outfall there are 13 precipitation channels, varying in length from 1,200 feet to 860 feet, each being 30 feet wide and holding collectively 20,000,000 gallons. The sewage flows in at one end of each channel, and after the heavier matters are precipitated, the effluent, viz., the clarified sewage, goes over a weir at the other end of the channel into the river. After a certain period each channel is shut off from the inlet of sewage, and the heavier matter left in the channel is dealt with as described later on. Each channel is shut off in succession, and, as a rule, is shut off once in 60 hours; this period varies slightly according to the character of the sewage, but, whatever its length may be, it is known as the "channel hours." The procedure followed in dealing with the removal of the sludge in a channel is as follows:—

Wet sludge.

> After the inlet valves to the precipitation channels are shut, the top or supernatent water in the channel is run off through floating arms or lowering weirs, into the effluent culvert leading to the river. After all the top water is run off, the matter remaining at the bottom of the precipitation channel, is known as "wet sludge." This wet sludge is pushed by hand labour into the sump under the sludge pumps. On its way to the sump, the sludge passes through screens in order to collect rags, wood and other materials that might injure or clog the pumps. From the sump, the sludge is pumped to the sludge settling channels, where it remains for about 24 hours. The supernatent water on the top of the settled sludge is known as "liquor," and is of a very foul nature, and is drawn off by means of telescopic weirs, and is pumped up to the outfall sewer to mix with the rest of the sewage, but before reaching the sewer, it is treated with 20 grains of lime and 10 grains of iron per gallon. The settled sludge (which contains about 92 per cent. of water) from the sludge settling channels gravitates to the sludge store, from which it is pumped to the sludge ship and sent to sea.

Similar methods are pursued at Crossness.

The clarified liquid is discharged continuously into the river at both Barking and Crossness, at all states of the tide.

Before the construction of the precipitation works, the crude sewage was pent up during the whole period of the flood and only let out on the ebb tide.

Sludge.

The sludge is pumped into sludge steamers and conveyed to the Black Deep, about 57 miles below Barking, the area in the Thames estuary where deposit is now allowed to be made. The sludge is there discharged over a length of 8 to 10 miles. Each sludge vessel carries about 1,000 tons and travels about 110 miles each trip; six steam sludge vessels are constantly at work. About 8,200 tons of sludge were sent to sea daily last year.

Bacterial Treatment of sewage.

Although the treatment of sewage bacteriologically, has been adopted in many large inland towns, this method has so far not been used except experimentally at the outfalls at Barking and Crossness. While it is absolutely necessary in the case of inland towns, that the sewage from large populations discharging into small streams, should be purified to as great an extent as possible, the same necessity does not arise in the case of London, where the sewage is discharged several miles below the metropolis, into a large river with great tidal capacity. The London County Council was, however, one of the first authorities to experiment on a large scale on the bacteriological treatment, and a one-acre coke bed was laid down at Barking in 1893 on the advice of Mr. W. J. Dibdin, who was then the Council's chemist, and under the superintendence of Sir Alexander Binnie. Although this bed is now in a more or less derelict condition, the upper half of the bed is still used for the purification of about 350,000 gallons of sewage per day. The bed is about 6 feet deep, but the lower half has become very much crushed and consolidated, and is practically useless. A large number of experiments on a smaller scale were also carried out by Mr. Dibdin, and latterly by Dr. Clowes, the Council's Chemist, so as to obtain as much information as possible on the subject. The results of Dr. Clowes' experiments have been published by him, in 1904, under the head of "The Experimental Bacterial Treatment of London Sewage," which covers all the experiments carried out by the London County Council, as regards that method of treatment between the years 1892 and 1903. Attached to Dr. Clowes' report is also a report by Dr. Houston, who was specially appointed by the Main Drainage Committee to investigate, from the bacteriological point of view, the experiments in progress at Barking and Crossness on the bacteria bed treatment of sewage. The complete work by Dr. Clowes and Dr. Houston forms a valuable contribution to the knowledge of this subject, and is a useful book of reference.

Owing to the large number of inland towns which have now adopted the bacterial treatment of sewage, the results of experiments on a small scale are not of such value and interest as the results

Bacterial treatment of sewage—*continued.*

on a large scale, which are now available in many places. It does not, of course, follow, that the actual treatment used at one town will be the best for any other town, as the nature of the sewage may be totally different. In many towns the treatment of the trade refuse which has to be taken into the sewers is one which requires very careful consideration, but, generally speaking, the bacterial treatment of sewage in many large towns has now been successful enough, to give useful information on all the different methods which have been employed.

Since the experimental coke-bed was first constructed at Barking in 1893, the whole question of sewage purification by bacterial methods in artificial filters has undergone, *and is still undergoing*, considerable development. This is evident by the fact that in the case of Manchester, chemical precipitation has been given up in favour of septic treatment, followed by primary and secondary contact beds. At Salford, chemical precipitation is still in use, but the effluent is further treated on percolating filter beds. At Birmingham chemical precipitation has been abandoned in favour of septic treatment and percolating filter beds. At Sheffield, chemical treatment is about to be given up in favour of sedimentation and primary contact beds. At Leeds, chemical treatment is in use, but in the near future the effluent will probably be treated on percolating filter beds. At Accrington, septic treatment is now in use together with rotary percolating filter beds, and at Croydon, sedimentation and rotary percolating filter beds have been recently adopted, but as the Corporation is in possession of a very large sewage farm, the final effluent from the filter beds passes over the land before going into the River Wandle. In these and many other cases the results obtained may be useful for the guidance of London in future years.

There is no doubt that, as the population of London increases, it may be necessary at a future date to adopt special methods for treating, in some way other than chemically, a portion of the sewage, so as to improve the quality of the effluent now discharged into the river. It does not, however, appear that the volume of the effluent at the present time, is so large in comparison with the volume of the river, as to cause any serious annoyance, and in connection with this the conclusions of the Royal Commission on Sewage Disposal, in their Fourth Report in 1904, are of interest and are as ollows :—

> " We have also undertaken an examination of the River Thames and Thames estuary. In connection with this investigation the question of the disposal of the London sludge and other refuse in the open sea has been considered, and for purposes of comparison, some analyses have been made of the River Thames at Sunbury and Hampton, above the intake of some of the London waterworks companies. These matters are dealt with by Dr. Houston in his report on the River Thames and Thames estuary, which is published in the separate Appendix to this Report. One of the reasons for making this investigation was the allegation that the discharge of the imperfectly-treated sewage of London into the river at Barking and Crossness, and the deposit of sludge and refuse in the open sea at Barrow Deep were causing grave evils.
>
> As a result of these investigations, we find that, as judged by the B. coli test, the River Thames at Mucking, about 20 miles below the Barking and Crossness Outfall Works, is at times as pure as the River Thames in the region of Sunbury and Hampton, above the intakes of some of the London waterworks companies.
>
> As regards change in the biologcal composition of the water in the River Thames, from Barking and Crossness downwards towards the open waters of the estuary, all that need be said is, that whereas at Barking and Crossness the number of B. coli per c.c. of water, varied usually from 100 to 1,000, no appreciable improvement was noticeable at Purfleet (about 5 miles below Crossness), but slight improvement at Grays (about 10 miles below Crossness), and that it is not until Mucking (20 miles below Crossness) is reached, that the quality of the water is so far improved as to vie with the water in the Upper Thames at Sunbury and Hampton. At Mucking the number of B. coli per c.c. varies usually from 1 to 10, and about 5 miles lower down (at the Chapman light), it is so far improved that about one-half of the samples contained only one-tenth of this amount.
>
> These results do not support the allegation that the Kent and Essex foreshores beyond the Chapman Light, are greatly contaminated by the discharge of imperfectly-purified sewage into the Thames at Barking and Crossness."

The Main Drainage Committee of the London County Council has, however, realised that it is necessary at the present time to obtain land for the purposes of the further treatment of London sewage, as, if that land is not at once acquired, the neighbourhood around the outfall works would quickly get built over. On this account an area of between 500 and 600 acres has been bought at the outfalls in anticipation of the further treatment of London sewage, either by bacterial or other methods. Whenever it may be necessary to take these further steps it will not, of course, be either possible or desirable to deal with the whole of the London sewage at once. No doubt, in the first instance, a small percentage would be dealt with, and gradually as the population increased, the additional sewage would be specially treated. It is generally recognised that the discharge of a very considerable amount of clarified effluent into the Thames, does no harm owing to the large volume of the river itself, and it would therefore be a waste of money to deal bacterially with the whole of the London sewage at any future date.

The Council on the 17th December, 1889, passed the following resolution :—

That this Council desires further information upon the question of sewage disposal, more especially with a view to the prevention of disease and freeing the river from pollution.

Report by Sir Benjamin Baker and Sir Alexander Binnie, 1891.

In consequence of this resolution, the Main Drainage Committee, on the 17th January, 1890, requested the late Sir Benjamin Baker and Sir Alexander Binnie (at that time Engineer to the Council) to report upon :—

(1) The operations at the precipitation works.
(2) The condition of the river.
(3) The movement of the effluent in the river.
(4) The state of the mud-banks.
(5) The pollution of the river.
(6) The cost of taking the whole of the sewage to sea and the approximate route.
(7) The most economic use of the existing works.
(8) The capacities of the existing sewers.
(9) The provision of storm overflows and the best means for avoidance of floodings.

Sir Benjamin Baker and Sir Alexander Binnie reported to the Main Drainage Committee, in February, 1891, and the following is a summary of their report and conclusions :—

(1) Questions submitted many and wide. Chief attention has been devoted to those demanding earliest solution.

(2) General features of the main drainage system unalterably fixed many years ago.

(3) Certain amount of sewage pollution in river inevitable during heavy rainfall.

(4) Chief public complaint—insufficient size of main sewers, causing floodings and frequent discharge of crude sewage into the river, in the heart of the Metropolis.

(5) Proposed new intercepting sewers for both sides of river—estimated cost £2,250,000.

(6) No urgency exists as regards removal of outfalls. No new works at outfalls should be made until precipitation works have had a fair trial.

(7) During the past half century, the river has never been free from sewage pollution, and experience has shown that, provided that such pollution be kept within reasonable limits, no practical inconvenience results therefrom.

(8) The whole of the future sewage should not be dealt with at the existing outfalls ; it was suggested that an outfall should be found for a portion of it at a lower point in the river.

(9) There is no point in the estuary of the Thames, or on the Essex coast near thereto, where the whole of the future sewage could be discharged in a crude condition without risk of returning up the Thames and other rivers.

(10) If the sewage must be treated at a new outfall, it might conveniently be placed at Shell Haven in Sea Reach.

(11) Land might be reserved at any new outfall to enable the sludge to be in part dug into the soil, but it would probably be found better to use sludge ships.

(12) Practically it might be said that the sewage would be entirely taken to sea, but instead of being discharged in a crude condition at one point, it would be dealt with in two portions, the clarified sewage being discharged some distance up the estuary and the sludge being deposited many miles out at sea.

(13) The estimated cost of works for conveying the whole of the crude sewage to sea, £8,000,000 ; working expenses, £80,000 per annum. Estimated cost of works, for discharging a proportion of the sewage in a clarified condition at Shell Haven, £1,600,000. Working expenses £50,000 per annum, plus the cost of precipitation and conveyance of the sludge to sea.

(14) As growth of population is gradual, the sewage system should also be of a progressive character. Such portions of the works included in our estimate of £2,250,000, as are of pressing necessity, should be at once commenced. The remainder of the works including the proposed new outfall should not immediately be proceeded with.

Approximate estimated cost of proposed new works, which consisted mainly of new sewers, referred to in paragraph 5 of the summary of report :—

North side of river.	
Outfall sewer, Old Ford to Barking	£620,000
Intercepting sewer, Paddington to Old Ford	245,000
Separation of Isle of Dogs, and Hackney branches including pumping engines	55,000
South side of river.	
Low-level sewer, Deptford to Crossness	£427,000
High-level sewer, Dulwich to Crossness	784,000
Engines and buildings at Crossness	89,000
Total estimated cost	£2,220,000

In April, 1891, the Council, after considering the above report, issued an instruction to the Engineer to prepare drawings for all the works recommended.

In November, 1891, the Engineer reported to the Main Drainage Committee upon the proposed Isle of Dogs Relief sewer, which, together with additional pumping power at Abbey Mills, was approved, and in due course carried out.

A new sewer was also made from Hackney to Abbey Mills at a later date.

After that the matter for the time being remained more or less in abeyance, but on the 9th December, 1897, the Main Drainage Committee issued the following instruction :—

> Engineer to further consider the general question of the condition of the whole main drainage system of the Metropolis, and to submit his best advice to the Committee under all the circumstances, due regard being had to the prevention of local floodings.

Report by Sir Alexander Binnie, 1899.

Sir Alexander Binnie reported that the following works were the most urgent, and stated that the cost might roughly be taken as follows :—

Proposed New Works, 1899.

North side of river.	
Two sewers, Old Ford to Barking...	£725,000
New middle-level sewer, Paddington to Old Ford	270,000
New low-level sewer ...Hammersmith to Bow	500,000
Extension of middle-level sewer to Scrubbs-lane, Willesden	12,000
Pumping machinery at Abbey Mills	120,000
South side of river.	
Low-level sewer, Deptford to Crossness	500,000
High-level sewer, Catford to Crossness	520,000
Low-level sewer, Battersea to Deptford	300,000
Total approximate estimate...	£2,947,000

The above scheme was submitted to the Council by the Main Drainage Committee on the 5th December, 1899, when the Council sanctioned a preliminary vote of £1,250,000—other votes have been passed at later dates.

The greater part of the above works have now been executed. Some of them are still being carried out and others are nearly ready for contract. It is hoped that within two or three years the whole of the new works will be in operation.

The construction of the above sewers was begun on the 21st January, 1901, when the order to commence was given for the first portion of the enlargement of the northern outfall sewer, and since that time 20 main contracts (excluding machinery), of an aggregate value of about £3,000,000, have been entered into for the construction of the various portions of the new works, the individual contracts varying in amount from £13,000 to £437,000. One more large contract is in preparation, and tenders will shortly be invited.

Owing to the area in London occupied by buildings, railways, pipes, etc., being now so much larger than it was at the time the first main drainage works were carried out, the routes of the various sewers have been matters requiring much consideration. The recent construction of tube railways in London has also added to the difficulties. To avoid making many working shafts, and also to reduce the amount of pumping in waterlogged ground to a minimum, and also to cause the least amount of disturbance and possible injury to property, some of the sewers have been constructed with cast-iron segments, bolted together in rings and lined inside with concrete and brickwork. Much of the work has also been carried out, or is in course of execution or will be executed, by the aid of a shield, and where the nature of the ground requires it, or for other reasons, compressed air is employed as a precaution and to avoid pumping.

The new sewers already in operation (although only part of the whole scheme now in progress) have diminished to a great extent the number of discharges during rainstorms into the river Thames within the county of London. As previously mentioned, before 1901, the stormwater discharges into the Thames were frequent, even with comparatively light rainfalls, and the first flow of rain off the streets and the deposits in sewers stirred up by the rain (both of a very objectionable character), were delivered direct into the river. Now the bulk of this water is carried to the outfalls and treated before it is discharged into the Thames, and there will be a still further improvement in this respect as soon as the complete scheme of new sewers comes into operation.

Flood Relief Works.

Long before the present main drainage system of intercepting sewers was inaugurated, the principle of "combined" drainage had been adopted in London, viz., each house had only one drain conveying both sewage and all rain water ; this drain connected, therefore, with only one local sewer in each street ; these local or branch sewers connected in their turn with the main sewers, which latter discharged their combined rain and sewage directly into the Thames.

In towns where the "separate" system prevails, each house has two distinct sets of drains, one for sewage and one for rain water, and each street has also two sewers, one for sewage and the other for rain water. Under this arrangement the flow in the sewage sewers is always normal, and can be calculated with accuracy ; there can be no surcharging, and the backing up of sewage into the house by reason of excessive rainfall is rendered impossible.

To alter the prevailing system in London was, of course, recognised, from the very first initiation of the present main drainage system in 1856, as quite impossible in a city containing at that time 2½ millions of people ; the adoption of a separate system at this stage would have involved the redraining of every existing house, and the pulling up of every existing street ; such an upheaval could not be contemplated for a moment. Nevertheless, whatever the function of the branch and main drains, it was not necessary or practicable to construct all the new intercepting sewers of such a capacity that they should be capable of conveying to a point miles below the eastern boundary of the Metropolis at Bow-creek, all the water that would be carried to them by the local and main sewers. In times of heavy rain this would mean that the intercepting sewers must be capable of dealing with

Flood Relief Works.

practically the whole of the rainfall within the area of the Metropolis, as in paved streets and on areas covered with houses absorption and evaporation is reduced to a minimum. The impossibility of making a sewer capable of performing a function of this sort is clearly brought out in Sir Benjamin Baker's and Sir Alexander Binnie's report of 1891, where it is stated that a rainfall of half an inch an hour, flowing off the area drained on the north side of the Thames, viz., 50 square miles, would require a channel 500 feet wide, 10 feet deep, flowing with a velocity of 200 feet a minute.

The designers of the present main drainage system therefore provided for only a very small amount of rainfall, to be mixed with the sewage and conveyed to the outfalls, and deemed it to be more economical and more efficacious to discharge the bulk of the storm water direct into the the Thames, in the quickest possible manner.

To effect this, many of the main sewers *above the level of high water* are relieved in times of heavy rain by means of storm water sewers, which operate only on these occasions, and discharge their contents directly into the river ; this they can do whether the tide is high or low, by reason of the fact that they are capable of being put under pressure without damage. From the low-lying districts below Trinity high-water level adjacent to the Thames, both on the north and south side, and which are together about 10 square miles in extent (see plan No. 2 at end of book), the storm water cannot always be discharged by gravitation, and it must therefore be pumped ; having regard to the vast quantity of water that may have to be got rid of in this way during a severe storm from the area above mentioned, it is evident that the pumping stations should be of large capacity and in suitable situations.

Plan No. 2.

The late Metropolitan Board of Works and the Council accordingly erected the six pumping stations, which are now exclusively used for this purpose, and which are capable of lifting in the aggregate about 300,000 gallons a minute. Three of these pumping stations are on the north side of the river, viz., Lot's-road, King's Scholars' Pond and Isle of Dogs, and three are on the south side, viz., Falcon Brook, Heathwall and Shad Thames. Provision has also been made in two of these stations, viz., at the Falcon Brook pumping station and at the one lately erected at Shad Thames, for doubling their capacity whenever this course seems necessary.

In addition to the pumping power above referred to, arrangements are also made by means of auxiliary engines for discharging storm water direct into the river at two of the ordinary sewage pumping stations, viz., the Western pumping station and at the North Woolwich pumping station.

The following extract from Sir Joseph Bazalgette's annual reports, with the flood relief scheme proposed by him on 1st August, 1879, will be of interest

Extract from Sir Joseph Bazalgette's Twenty-third Annual Report, 31st December, 1878.

"The subject of relieving various low-lying parts of the Metropolis from the flooding to which they are subjected on occasions of very heavy rainfall has been for some time past, and still is, receiving a considerable amount of attention from the Board. The intercepting sewers constructed by the Board were not designed for the purpose of taking all the waters which fall during excessive rainstorms, such, for instance, as the one which occurred on the 10th and 11th April last, when, from observations made at 43 stations in and around the Metropolis, it was estimated that an average of 2·64 inches of rain (or nearly one-seventh of the average yearly rainfall) had fallen over the whole of the Metropolitan area within a period of 19 hours. To intercept such a volume of water as resulted from this rain, would have necessitated the intercepting channels being constructed of the capacity of rivers, and which channels would have been nearly empty, excepting on occasions of extraordinary rainfall. The intercepting sewers were designed to carry away from London its sewage, the bulk of which has first been artificially brought into the Metropolis as water supply, and with it a limited quantity of rain equal to one-fourth of an inch in twenty-four hours. Whilst, therefore, these intercepting sewers afford a very considerable relief, and have very materially reduced the floodings of former years, the works necessary for dealing with the floods arising from excessive rainfalls must be independent of, and in addition to, the intercepting sewers."

In a report of the 13th May, 1878, referring to the rainfall above mentioned, Sir J. W. Bazalgette stated that in some places the rainfall was over 3 inches and at Haverstock Hill it was 4·27 inches. This fall appears to have extended over 19 hours, but an even worse case had been reported in 1867, when on 27th July in that year, 3¼ inches of rain fell in 9 hours

The Metropolitan Board of Works, in consequence of many complaints, decided, on 1st August, 1879, to carry out the following works:—

Storm relief line for the Ranelagh and King's Scholars' Pond sewers	£196,000
Storm relief line for the Ratcliff-highway and Limekiln Dock sewers	56,000
Relief line for high-level sewer at Hackney	52,000
Intercepting sewer from Putney to Clapham	170,000
Storm relief to high-level at High-street, Clapham, to discharge into Effra-creek, Vauxhall...	70,000
Deptford storm overflow	10,000
Sewer from Lee Bridge to Deptford	30,000
Sewer to relieve low-lying ground at Walworth...	60,000
Storm sewer to relieve Holloway and Kentish Town	64,000
Total estimated cost	£708,000

NOTE.—All the above sewers were constructed with the exception of the sewer at Walworth, but a relief sewer was made from Rotherhithe-new-road to Southwark ; this sewer is now known as the Grange-road sewer.

Heavy rainfall and floodings, June, July, August and September, 1903.

Notwithstanding the extensive storm relief works carried out by the Metropolitan Board of Works, floodings occurred in many parts of the Metropolis at times of storms; this was especially the case in 1903, when, during June, July, August and September, the rainfall in London was exceptionally heavy, and many places were flooded that had never been flooded before. During the four months mentioned, there were 12 days on which the rainfall exceeded half an inch in 24 hours, and on the 23rd July the large amounts of 2·97 inches and 3·59 inches in 24 hours were recorded at Deptford and Abbey Mills respectively. Over a thousand complaints of flooding were received, both from the borough councils and from private persons. The rainfall during 1903 amounted to the unprecedented total of 35 inches.

Report on floodings by Chief Engineer, November, 1903.

After investigating the matter to the fullest extent the Engineer fully reported to the Main Drainage Committee on the 19th November, 1903, and submitted the following flood relief works, which were adopted by the Council on the 16th February, 1904:—

Suggested Flood Relief Works.

North side—	
1. Storm relief sewer, Holloway to the Thames	£250,000
2. Storm relief sewer from middle-level sewer to Counters-creek sewer [North Kensington storm relief sewer]	20,000
3. Extension of Hackney Wick relief sewer northwards	70,000
4. Stroud Green storm relief sewer	25,000
Smaller works	40,000
South side—	
5. Storm water pumping station at Wandsworth [Falcon-brook pumping station]	50,000
6. New sewers in connection with above pumping station... ...	50,000
7. Storm water pumping station to deal with storm water in Southwark and Bermondsey [Shad Thames pumping station] ...	50,000
8. Sewer to above from St. George's-circus*	40,000
9. Sewer to above from Bermondsey*	40,000
Smaller works	35,000
	£670,000
Contingencies	67,000
Total estimated cost	£737,000

North side of river.

On the north side of the river the floodings in Hammersmith and Fulham will, it is thought, be relieved by the construction of the new northern low-level sewer (*see* p. 8) between Hammersmith and Bow, of which about 2 miles at each end have been completed and the remaining length is being proceeded with.

The new sewer for relieving the floodings in North Kensington (No. 2 above) has been constructed.

The floodings in Hornsey and Stroud Green have been relieved by the new relief sewer (No. 4 above) which is now in operation.

With respect to the floodings in the north-east corner of Hackney, a new sewer (No. 3 above) is in course of construction across Hackney Marshes and will form an extension of the Abbey Mills to Hackney Wick relief sewer, constructed by the Council in the year 1899.

The plans for the proposed relief sewer from Holloway to the Thames (No. 1 above), near the Tower of London, have been prepared, and an agreement with the Crown for the outlet has been entered into, but at present it is not proposed to proceed with this sewer, as the new middle-level sewer (page 8), which is in process of construction and will very soon be completed, will give relief to the high-level sewer, and it may not be found necessary to carry out this particular relief sewer until a later date.

South side of river.

On the south side of the river a storm relief sewer has been constructed to relieve floodings in Wandsworth and Battersea (No. 6 above), and the Falcon pumping station at Battersea (No. 5 above) has been reconstructed and reopened. This pumping station was closed in the year 1898, and was reopened in July, 1907. It may be mentioned that the local authorities at Battersea particularly urged the reopening of this station, by means of which, and the existing pumping station at Heathwall, the low-lying areas in Wandsworth and Battersea are materially relieved in times of heavy rain.

The Southwark and Bermondsey storm relief sewer (Nos. 8 and 9 above) has been constructed, and a new pumping station at Shad Thames (No. 7 above) in connection therewith has been completed. This sewer, it is anticipated, will be capable of dealing with the floods complained of in Southwark and Bermondsey.

As regards the floods in Lewisham, Greenwich and Woolwich, these have been, it is believed, provided for by the construction of the new high-level sewer from Catford to Crossness, and the completion of the new southern outfall sewer from Deptford to Crossness.

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* These proposed works were executed as one sewer, "the Southwark and Bermondsey storm relief sewer."

Bdg.

As regards floodings in Lambeth, Camberwell and other places, the proposed new southern low-level sewer from Battersea to Deptford, the plans for which are practically ready, will no doubt afford effective relief when it is completed and in operation.

General Remarks.

Since the London County Council was constituted in 1889, in addition to the flood relief works already referred to, the capacity of the main drainage system has been nearly doubled, and the following works have either been completed or are in process of execution or preparation :—

North side of river.

Upon the north side of the Thames two new sewers, each 9 feet by 9 feet, have been constructed from Old Ford to Barking, a distance of 5½ miles—these form an addition to the northern outfall sewer. At Abbey Mills pumping station, a new storm-water engine house, capable of lifting 150,000 gallons per minute, is in contemplation and the plans are now being prepared. A new middle-level sewer from Willesden to Old Ford, a distance of 9 miles, is almost completed. A new low-level sewer from Hammersmith to Bow, a distance of 12¼ miles, has been partially executed, the last contract from West Kensington to Grosvenor-crescent having recently been let.

South side of river.

Upon the south side a new outfall sewer, 11 feet 6 inches diameter, has been constructed from Deptford to Crossness, a distance of 7¼ miles, and a new high-level sewer, partly 10 feet and partly 11 feet 6 inches diameter, has been constructed from Catford to Crossness, a distance of 8¼ miles. Additional engine power, with the requisite houses, cooling ponds, etc., have been provided both at Deptford and Crossness. A new low-level sewer from Battersea to Deptford, 7 miles long, is intended to be constructed, the plans being nearly finished for the main portion—the western end of the sewer in Wandsworth having already been executed.

Discharging power at outfalls.

The total discharging power of the northern outfall sewer at Barking, under the present conditions, is about 500,000,000 gallons, and of the southern outfalls at Crossness 513,000,000 gallons per day of 24 hours.

In conclusion, it may be a matter of convenience to briefly summarise the extent of the main drainage works, and of the operations which are carried out under the direction of the Main Drainage Committee.

Population of main drainage area.

The population of the area (about 140 square miles) draining into the Council's sewers in 1901 was 5,136,192.

Population of London compared with other towns.

As regards these figures, it should be observed that at the date above named they equalled the combined populations of Glasgow, Liverpool, Manchester, Salford, Leeds, Birmingham, Sheffield, Newcastle-on-Tyne, Bristol, Hull, Dublin, Belfast, and Edinburgh, or, in other words, eight times that of Glasgow.

Daily flow of sewage.

The average daily flow of sewage to Barking and Crossness in 1908 was 283,000,000 gallons, which, during times of storm, may be augmented up to 1,008,000,000 gallons, or even more if the sewers were surcharged.

Men employed.

To deal with this quantity of sewage between 900 and 1,000 men are employed—this includes all the labour of cleansing the main, the intercepting and the outfall sewers, all the work at the pumping stations and the working of the sludge boats.

Capital expenditure.

The net capital expenditure on the main drainage works by the Metropolitan Board of Works was	*£6,824,877
Since the Council came into office in 1889, up to the 31st March, 1909, there has been a further expenditure of	*4,285,512
Total expenditure to 31st March, 1909	£11,110,389

There will be a further probable expenditure in order to complete the main drainage and flood relief schemes sanctioned by the Council of about £1,500,000.

The capital expenditure incurred by the Council on the main drainage system during the five years ending 31st March, 1908, was £2,225,114.

As regards the works that have been executed by the Metropolitan Board of Works and by the Council, the following tables set out the principal works carried out by these respective authorities; a few works of a minor character are not included.

The various sewers and pumping stations are indicated on Plan No. 1 at the end of the book, those constructed by the Board being indicated in green colour and the works constructed by the Council being shown in red.

North side of the Thames.

Principal main drainage works carried out by the Metropolitan Board of Works.

	Miles.
Northern high-level sewer	7½
Northern middle-level sewer	9½
Piccadilly branches	2¾
Northern low-level sewer	8¼
Hackney branch (Wick-lane)	2½
Isle of Dogs branch	1⅞
Western sewers—	
Main line	5⅛
Fulham branch	1⅓
Acton line	1⅜

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* For these figures I am indebted to the Comptroller.

Northern outfall sewer, 3 culverts, from Abbey Mills to Barking, each 9 feet by 9 feet (4½ miles)—Discharging capacity when full, 206,250 gallons per minute.

Abbey Mills pumping station—Pumping capacity, 109,312 gallons per minute.

Western pumping station at Pimlico—Pumping capacity, 46,592 gallons per minute.

Barking reservoir (9½ acres). Capacity, 35,000,000 gallons.

Main drainage works on the north side commenced by the Metropolitan Board and finished by the Council.

Precipitation works at Barking.

Principal main drainage works carried out by the London County Council.

Isle of Dogs relief sewer.

Brook Green diversion sewer.

North Woolwich sewer.

Enlargement of northern outfall sewer (two sewers, each 9 feet by 9 feet)—Discharging capacity when full, 137,500 gallons per minute.

Hackney and Abbey Mills relief sewer and extension of same.

Abbey Mills pumping station—Additional pumping capacity, 25,984 gallons per minute.

North Woolwich pumping station—Pumping capacity, including storm water and sewage, 11,724 gallons per minute.

Main drainage works partly finished and partly in course of execution.

	Miles.
Northern low-level sewer No. 2 (Hammersmith to Bow)	12¼
Northern middle-level sewer No. 2 (Willesden to Old Ford)	9

South side of the Thames.

Principal main drainage works carried out by the Metropolitan Board of Works.

	miles.
Southern high-level sewer	5⅜
Effra branches do.	7¼
Southern low-level sewer	9½
Bermondsey branch	2¾
Southern outfall sewer	7½

(Discharging capacity when full, 118,750 gallons per minute).

Clapham and Putney sewer (Southern high-level sewer extension).

Grange-road sewer.

East Greenwich branch sewer.

Deptford pumping station—Pumping capacity, 90,496 gallons per minute.

Crossness pumping station—Pumping capacity, 112,000 gallons per minute.

Crossness reservoir (6½ acres). Capacity, 25,000,000 gallons.

Main drainage works on the south side commenced by the Metropolitan Board but finished by the Council.

Precipitation works at Crossness.

Principal main drainage works carried out by the London County Council.

Southern high-level sewer No. 2 (Catford to Crossness) (8¼ miles)—Discharging capacity when full, 118,750 gallons per minute.

Southern outfall sewer No. 2 (Deptford to Crossness) (7¼ miles)—Discharging capacity when full, 118,750 gallons per minute.

Loampit-vale to Bell-green sewer.

Crossness pumping station—Additional pumping capacity, 62,720 gallons per minute.

Deptford pumping station—Additional pumping capacity, 45,696 gallons per minute.

Main drainage works—Partly finished and partly in course of execution.

Southern low-level sewer No. 2 (Battersea to Deptford) (8 miles).

North side of the Thames.

Principal flood relief works carried out by the Metropolitan Board of Works.

Ranelagh storm relief sewer.

High-level and Ratcliff storm relief sewer.

Holloway storm relief sewer.

Fleet storm relief sewer.

Isle of Dogs pumping station—Capable of raising 15,232 gallons per minute.

Western pumping station—Auxiliary pumps, capable of raising 7,840 gallons per minute.

Principal flood relief works carried out by the London County Council.

Hackney and Holloway storm relief sewer extension (Amhurst-road to Mare-street, Hackney).
Extension of the Fleet storm relief sewer.
Mare-street and Morning-lane relief sewer
Hornsey and Stroud-green relief sewer.
North Kensington relief sewer.
Pumping station at Lots-road, Chelsea, capable of raising ... 115,584 gallons per minute.
Pumping station at King's Scholars' pond sewer, capable of raising ... ... 21,500 ,, ,,
Storm-water pumping station at Abbey Mills, capable of lifting 150,000 ,, ,,
(NOTE.—Plans for this station are in course of preparation.)

SOUTH SIDE OF THE THAMES.

Principal flood relief works carried out by the Metropolitan Board of Works.

Effra storm relief sewer.
High-level storm relief sewer.
Deptford storm overflow.
Earl storm outlet, Rotherhithe.
Storm outlet at River Wandle, Wandsworth.
Effra pumping station.*
Falcon pumping station.*

Principal flood relief works carried out by the London County Council.

Mitcham-lane storm relief sewer.
Balham-high-road relief sewer.
Southwark and Bermondsey storm relief sewer.
Wandsworth and Battersea storm relief sewer.
Pumping station at Falcon-brook, capable of raising ... 40,000 gallons per minute.
Pumping station at Shad Thames, capable of raising... ... 50,000 ,, ,,
Pumping station at Heathwall, Nine Elms-lane, capable of raising ... ... 58,000 ,, ,,

LENGTHS OF SEWERS.

	Miles.
The length of main, intercepting and storm-water sewers taken over by the Metropolitan Board of Works, or constructed by them, amounted at the time when the Board was dissolved to about	274
The length of the additional sewers constructed by the Council, including those in course of construction and those about to be constructed, amounts to about ...	78
Total length of main, intercepting and storm-water sewers will be about ...	352

DISCHARGING CAPACITIES OF OUTFALLS AND STORM-WATER PUMPING STATIONS.

	Galls. per 24 hours.	Galls. per 24 hours.
The total discharging capacity of the *outfall* sewers for sewage and rain water when flowing full, both on the north and south side of the river, when the Metropolitan Board of Works went out of office was	468,000,000	
In addition to this, the Board of Works had provided special pumping power for dealing with storm water on the north side of the river of a capacity of	†33,000,000	
		501,000,000
The Council, since it has been in office, has increased the discharging capacity at the *outfalls* by	540,000,000	
In addition, the Council have constructed additional pumping stations for the discharge of storm water direct into the river, of a capacity of	423,000,000	
		963,000,000
Total discharging capacity of the outfalls and storm-water pumping stations, on both sides of the river, per 24 hours (excluding the proposed storm-water pumping station at Abbey Mills)		1,464,000,000

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* These pumping stations were closed in 1898 on the opening of the new Heathwall pumping station.

† These figures do not include the discharging capacities of the Effra and Falcon pumping stations on the south side of the river which were closed in 1898, which together equalled 90,000,000 gallons per 24 hours, and some auxiliary pumping power at Crossness amounting to about 46,000,000 gallons per 24 hours, which is now removed.

The preceding totals do not include the discharging capacity of those storm relief sewers which act by gravitation.

Inasmuch, as of the preceding total discharging capacity, the dry weather flow for 24 hours for both sides of the river amounted in 1907 to 246,000,000 gallons, the balance remaining, amounting to 1,218,000,000 gallons, which (apart from the relief sewers discharging direct into the river) is equivalent to a rainfall of 0·71 inches over the whole area of the Metropolis in 24 hours.

PUMPING STATIONS.

Of the 11 pumping stations belonging to the Council, there are five principal stations continuously employed in lifting sewage from one level to another; the motive power at these stations is steam, and they are as follows —

*Western pumping station, Pimlico	Total indicated horse power from 5,000 to 6,000.
Abbey Mills pumping station	
*North Woolwich Pumping station	
Deptford pumping station	
Crossness pumping station	

In addition to the above there are also ,as already stated, six pumping stations which only pump storm water into the river at times of excessive rain, and at which with one exception, viz., the Isle of Dogs station, the motive power is gas; these stations are as follows —

Lots-road pumping station	Total indicated horse power from 4,000 to 5,000.
King's Scholars' Pond pumping station	
Isle of Dogs pumping station	
Falcon-brook pumping station	
Heathwall pumping station	
Shad Thames pumping station	

The positions of the above pumping stations are shown on Plan No. 1.

The following table shows the quantities of crude sewage treated, chemicals used in precipitation and sludge sent to sea, together with the quantity of refuse intercepted at the gratings at each of the outfall works at Barking and Crossness during the year 1908 :—

		Barking.	Crossness.	Total.
Sewage treated...	gallons	57,360,341,000	46,102,176,000	103,462,517,000
Daily average	„	157,151,619	126,307,331	283,458,950
Lime used	tons	14,808	10,137	24,945
Proto-sulphate of iron used	„	3,289	2,786	6,075
Sludge produced and sent to sea ...	„	1,697.000	886,000	2,583,000
Weekly average	„	32,634	17,038	49,672
Number of trips made by the steamers	No.	1,697	886	2,583
Refuse intercepted at gratings ...	tons	3,465	1,089	4,554

TABLE SHOWING THE COST OF WORKING THE TWO OUTFALLS, INCLUDING THE SIX SLUDGE VESSELS, FOR THE YEAR 1907,

Barking and Crossness outfalls—	
Precipitation	£49,952
Sludge (land cost)	28,742
Sludge (sea cost)	39,486
Total cost of working	£118,180

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* At both these stations it is possible to pump storm-water direct into the river.

† This daily average flow is not the dry weather flow (which, of course, is less than the daily average), but it includes the proportion of rain water which is admitted to the sewers and treated in common with the crude sewage at the outfalls.

DEATH RATE OF LONDON.

It may be of interest to notice the gradual decline of the death rate, which is probably largely due to the effect of the main drainage works upon the health of the Metropolis.

The following table will show the steady and gradual decrease in the death rate since the year 1841 —

1841–50	24·8 per 1,000.
1851–60	23·7 ,,
1861–70 (Cholera epidemic in 1866)	24·4 ,,
1871–80	22·5 ,,
1881–90	20·5 ,,
1891–1900	19·1 ,,
1901–1905 (5 years)	16·1 ,,
1906	15·1 ,,
1907	14·6 ,,
1908	13·8 ,,

The bulk of the main drainage works were in operation in 1865, but the whole scheme was not actually completed till 1874.

The new works at Barking for treating the sewage with lime and iron and carrying the sludge to sea were completed in 1889. Similar works were completed at Crossness in 1891.

DISPOSAL OF THE SEWAGE.

The authors of the Metropolis Local Management Act, 1855, seem to have contemplated the possibility of profitable disposal of the London sewage, as there is a provision that the Metropolitan Board may sell or dispose of the sewage and refuse from the sewers as it may see fit, but so as not to create a nuisance (see section 135 of Act).

The notion that sewage might not only be-utilised in agriculture, but that it might become a profitable commodity was very prevalent forty or fifty years ago. The idea of making substantial profits out of the sale of town sewage, is now regarded as an illusion. The House of Commons in 1862, and subsequently in 1864, appointed committees to enquire into the question of the utilisation of sewage and the latter committee reported favourably thereon.

In 1865, the first year in which both the new sewage outfalls were in operation, the Board concluded an agreement with respect to the sewage of the north side of London, with the Hon. W. Napier and Mr. W. Hope.

Messrs. Napier and Hope proposed to take the sewage at Barking, and to convey it through culverts to the Foulness Sands, near the mouth of the Thames, where it was to be applied to the fertilisation of land to be reclaimed from the estuary.

In 1865, an Act of Parliament, called the Metropolis Sewage and Essex Reclamation Act, was passed, ratifying the agreement, and giving to the company to be formed under the Act, the powers necessary for the undertaking.

The company having been formed and a portion of the capital subscribed, a contract was entered into, and the works were commenced. After a time it appeared that the prospects of the adventure, were not sufficiently encouraging to lead investors to contribute the necessary funds. The undertaking languished, the works were suspended, and eventually abandoned. The periods mentioned in the original Act, and in an extension Act, having expired, the sum of £25,000 deposited with the Board by the promoters as security for the completion of the works was forfeited. This, it may be mentioned, is the only money the ratepayers of London have received in respect of their sewage, which was once considered to be of so much pecuniary value.

In 1880, the promoters of a scheme of utilisation obtained an Act of Parliament, called the Dagenham and District Farmers' Sewage Utilisation Act, after having come to an agreement with the Board to take the sewage from the *Northern Outfall Sewer.* They proposed to pump and convey it through a number of conduits, and to sell it for agricultural purposes in Essex. Previous experience did not lead the Board to anticipate any favourable results from the scheme, and, after the promoters had obtained their statutory powers, the Board heard nothing more of it. As regards the *Southern Sewage,* the Board considered favourably a tender by Mr. Ellis in 1866 and again in 1867, but owing to the want of financial support, Mr. Ellis's proposals fell through and nothing was done.

In 1872 the Native Guano Company carried out a prolonged experiment at Crossness under the system known as the A.B.C. process, but the Board finally came to the conclusion that there was no hope that the adoption of the process, would be of any advantage to the ratepayers.

Even now proposals are still put forward for utilising the sewage. One recent suggestion was that of an inventor, gifted with perhaps less knowledge but more imagination than his fellows, who proposed to supply the United Kingdom with alcohol from London sewage. Many curious proposals for making use of London sewage have been put before me from time to time by the large army of inventors, but no proposal has ever got beyond the preliminary stage. Several enthusiasts on the subject of the useful utilisation of sewage have begged for sample gallons of it at the outfalls, and one even took away a barrelful, but I have never again heard from any of them, and the amount of sewage which they have taken away has made no appreciable diminution in the 280,000,000 gallons a day which are still at the disposal of anyone who will take it in whole or in part. The fact of the matter is that the valuable matter, whether alcohol or other material in large quantities of sewage, is very similar to the gold which exists in all sea water, but which unfortunately costs more to extract than it is worth.

TABLE SHOWING WHAT IS DONE WITH THE SEWAGE IN TOWNS SIMILARLY SITUATED TO LONDON, VIZ., ON TIDAL RIVERS OR ESTUARIES:—

Name of place.	Population in 1901.	The undermentioned information is mostly obtained from Appendix VI. of the Fifth report of the Royal Commission on Sewage Disposal.
Belfast	349,180	Six-sevenths of the sewage in a crude condition is discharged into the Lough; the remaining portion of the sewage is treated in double contact bacteria beds.
Birkenhead	110,915	Crude sewage is discharged into the river Mersey at all states of the tide.
Bristol	328,945	The sewage is discharged in a crude condition into the river Avon at low water, excepting from two small districts remote from the main drainage system.
Dublin	290,638	The sewage is precipitated and the effluent discharged into Dublin Bay.
Glasgow	622,372	The sewage is precipitated at two outfall works and the effluent is discharged into the river Clyde—one at Dalmarnock and one at Dalmuir.
Hull	240,259	Crude sewage is pumped into the river Humber at all states of the tide.
Liverpool	684,958	Crude sewage is discharged into the river Mersey at all states of the tide.
Southampton	104,824	The sewage, after partial subsidence, is discharged into the River Itchen on the ebb tide.

It will be noticed that in only three of the above towns the sewage is precipitated, viz., Dublin Glasgow and Southampton, and at these three towns the effluent undergoes no further artificial purification; the crude sewage being discharged at Belfast, Birkenhead, Bristol, Hull and Liverpool.

LIST OF PLANS ACCOMPANYING THIS DESCRIPTION.

Plan showing positions of main, intercepting, outfall sewers, etc.	No. 1
Plan of low-lying land within the administrative county of London	No. 2
Plan of Barking Outfall Works	No. 3
Plan of Crossness Outfall Works	No. 4

DRAINAGE FROM OUTLYING DISTRICTS.

The boundaries of the Metropolis as defined under the Metropolis Management Act of 1855, were the artificial boundaries of the several parishes which formed the county of London, as set forth in the schedule of that Act. As these boundaries did not follow, as a rule, either valley lines or watersheds, it soon became evident that (notwithstanding the fact that the 1855 Act was essentially a drainage Act), difficulties would arise with those parishes on the borders of, but outside the Metropolis, which drained naturally into valleys falling towards the metropolitan drainage area, or, draining into sewers already constructed which were within or discharged within this area.

Other districts for various reasons also claimed to be allowed to convey their sewage to the outfalls at Barking and Crossness, through the medium of the great intercepting sewers, and the result was that from time to time a number of outlying places have, under terms, succeeded in inducing the Council, or their predecessors, to agree to admit and deal with their sewage.

The following table indicates when these districts were admitted, and also other particulars of interest; for some of this information I am indebted to the Statistical Officer.

MAIN DRAINAGE OF LONDON—DRAINAGE FROM OUTLYING DISTRICTS.

North of the Thames.

	Date of admission.	Area in acres.	Population when admitted.	Population of London at same date.	Annual payment 1908-9 per £ of rateable value.	Remarks as to areas, quantities, etc.	Name of London County Council sewer draining the outlying district.
					d.		
Hornsey (part)	1871	2,534	11,746	3,266,987	3·26	South Hornsey (now part of London) was admitted under special arrangements in 1874. As regards Hornsey the limits of quantity imposed by the Act of 1871 were repealed by the London County Council General Powers Act of 1906, with the proviso that the storm water should not be greater than passed into London prior to 1906.	High Level Sewer and Holloway Storm Relief Sewer.
Tottenham and Wood Green ...	1891	4,641	97,166	4,232,118	3·26	Sewage is admitted into London, but must not exceed 175 gallons per house. No rain water is admitted as the district is drained on the separate system.	Marsh Sewer and Hackney and Abbey Mills Relief Sewer Extension.
Willesden, "Metropolitan area" ...	1896*	1,154	43,485	4,433,018	3·26	Willesden had been draining into London since the days of the Commissioners of Sewers, but it was not until 1896 that payment was enforced by statute.	Ranelagh, Counters Creek and Stamford Brook Sewers.
Willesden, "Brent area"	Now being dealt with under Act of 1908.	3,230	—	—	—†	Quantity limited to 50 gallons per head per day of the approximate population for the time being, except with the consent of the London County Council.	Middle Level Sewer No. 2.
Acton	1908*	2,305	55,000	4,703,655	4·00	Quantity limited to 50 gallons per head per day of the approximate population for the time being. A part of Acton had been draining into London since the days of the Commission of Sewers, for which payment was enforced by the London County Council (Acton Sewerage) Act, 1898. This Act has been superseded by the Acton Sewage Act, 1905, under which the whole district drains into the metropolis.	Stamford Brook Sewer and Acton branch of the Low Level Sewer.
East Ham (part)	1900	78	3,000	4,536,541	3·26	Only that portion of East Ham which is situate to the southward of, and outside the southern boundary of the Royal Albert Dock.	North Woolwich Sewer.
West Ham	1900	4,706	267,358	4,536,541	2·25	Sewage from the whole area of the borough north of the Victoria and Albert Docks is drained into the northern outfall. Under certain conditions defined in the West Ham Act of 1893, the West Ham sewage may be shut off from the northern outfall sewer at Abbey Mills. The sewage from the remaining area of the borough south of the said docks gravitates to North Woolwich Pumping Station, and is then pumped to Barking.	As stated in preceding column.

Notes.—In addition to the above outlying districts, there are *very* small portions of Chiswick and Ealing and two houses in Edmonton draining into the metropolis.
For very small part of Tottenham draining into Hackney, and very small portion of Hackney draining into Tottenham, see London County Council General Powers Act, 1908, Sections 33 to 38.

* See remarks column.

† Willesden will pay in respect of the "Brent area" an annual contribution exceeding by 1½d. the rate paid in respect of the "Metropolitan area."

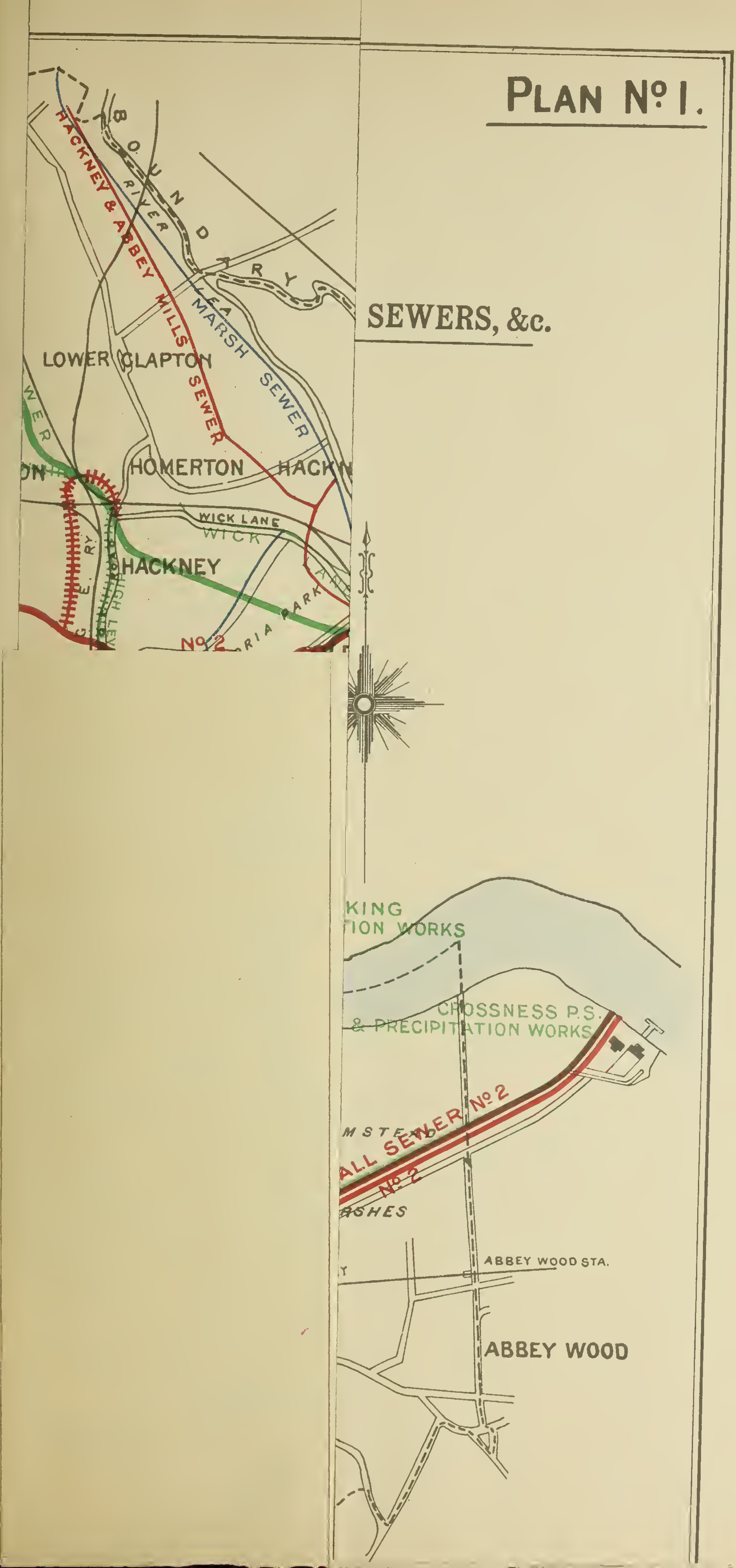
MAIN DRAINAGE OF LONDON—DRAINAGE FROM OUTLYING DISTRICTS.

SOUTH OF THE THAMES.

	Date of admission.	Area in acres.	Population when admitted.	Population of London at same date.	Annual payment 1908-9 per £ of rateable value.	Remarks as to areas, quantities, etc.	Name of London County Council sewer draining the outlying district.
Beckenham (part)	1873	589	—	3,373,282	*d.* 3·49	The area mentioned in column 3 is the only part allowed to drain into London, and no storm water is admitted.	Bell Green Sewer.
Penge	1900*	770	22,465	4,536,541	3·26	Penge originally formed part of the county of London, and as such contributed its share of the expenditure upon the main drainage system. It was severed from London by the London Government Act, 1899.	Bell Green Sewer.
Croydon—Norwood (part)... ...	1902*	346	8,600	4,536,541	3·26	All the sewage, drainage and surface water from the area which is immediately to the south of Westow Hill, Central Hill and Crown Hill. Croydon had been draining into London since the days of the Commissioners of Sewers, but it was not until 1903 that payment was enforced by statute. This provided for the payment of an annuity in respect of user prior to 1st April, 1902, and an annual contribution thereafter.	Effra Sewer.

NOTE.—In addition to the above outlying districts there is a small portion of Mitcham draining into the Metropolis.

* See remarks column.


PLAN Nº I.
SEWERS, &c.
BOUNDARY
RIVER
LEA
HACKNEY & ABBEY MILLS SEWER
MARSH SEWER
LOWER CLAPTON
HOMERTON
HACKN
WICK LANE
WICK
HACKNEY
Nº 2
KING
TION WORKS
CROSSNESS P.S.
& PRECIPITATION WORKS
ALL SEWER Nº 2
Nº 2
MSTEAD
RSHES
ABBEY WOOD STA.
ABBEY WOOD

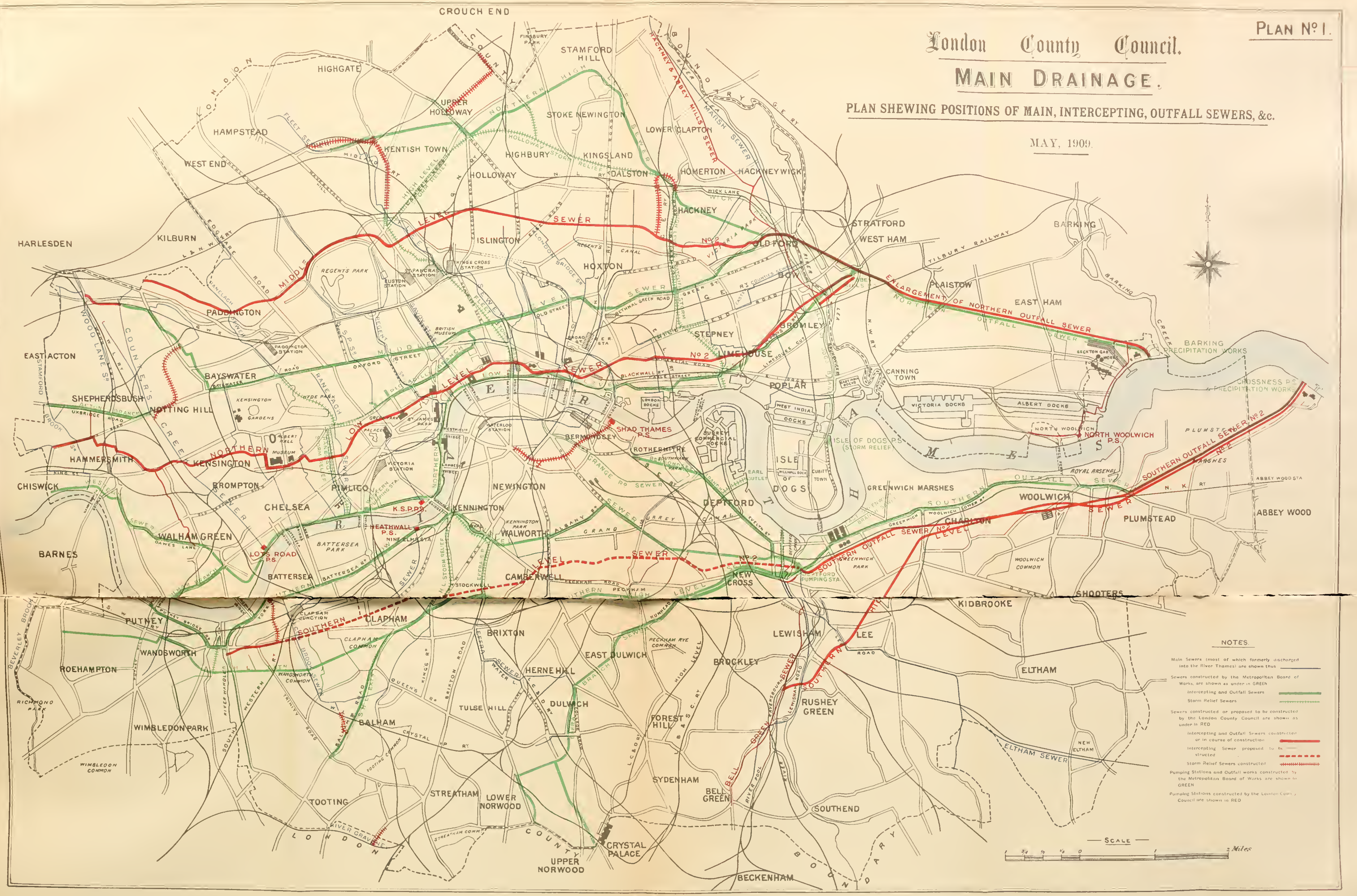
PLAN No I.

London County Council.

MAIN DRAINAGE.

PLAN SHEWING POSITIONS OF MAIN, INTERCEPTING, OUTFALL SEWERS, &c.

MAY, 1909.



NOTES.

Main Sewers (most of which formerly discharged into the River Thames) are shown thus ━━

Sewers constructed by the Metropolitan Board of Works, are shown as under in GREEN

Intercepting and Outfall Sewers ━━

Storm Relief Sewers ┿┿┿┿

Sewers constructed or proposed to be constructed by the London County Council are shown as under in RED

Intercepting and Outfall Sewers constructed or in course of construction ━━

Intercepting Sewer proposed to be constructed ╍╍╍

Storm Relief Sewers constructed ┿┿┿┿

Pumping Stations and Outfall works constructed by the Metropolitan Board of Works are shown in GREEN

Pumping Stations constructed by the London County Council are shown in RED

STRATIVE COUN

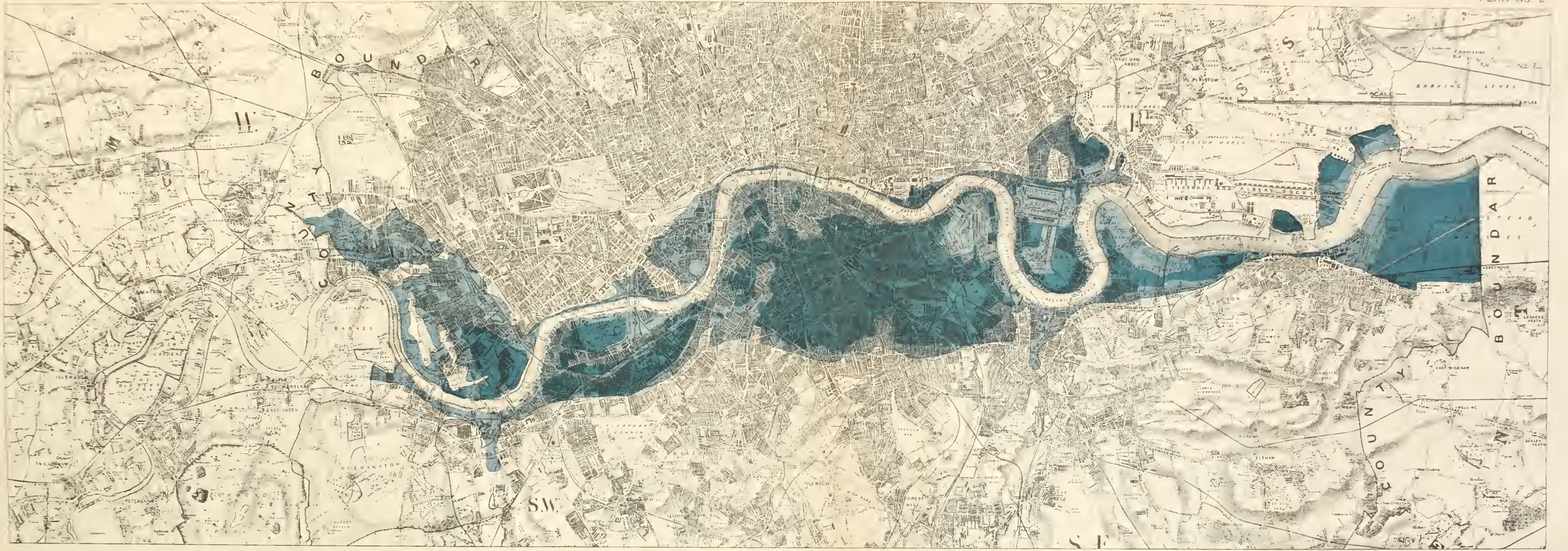
S. ABOVE ORDNANC

S. ,, ,,

LONDON COUNTY COUNCIL. MAIN DRAINAGE.

PLAN OF LOW-LYING LAND WITHIN THE ADMINISTRATIVE COUNTY OF LONDON.

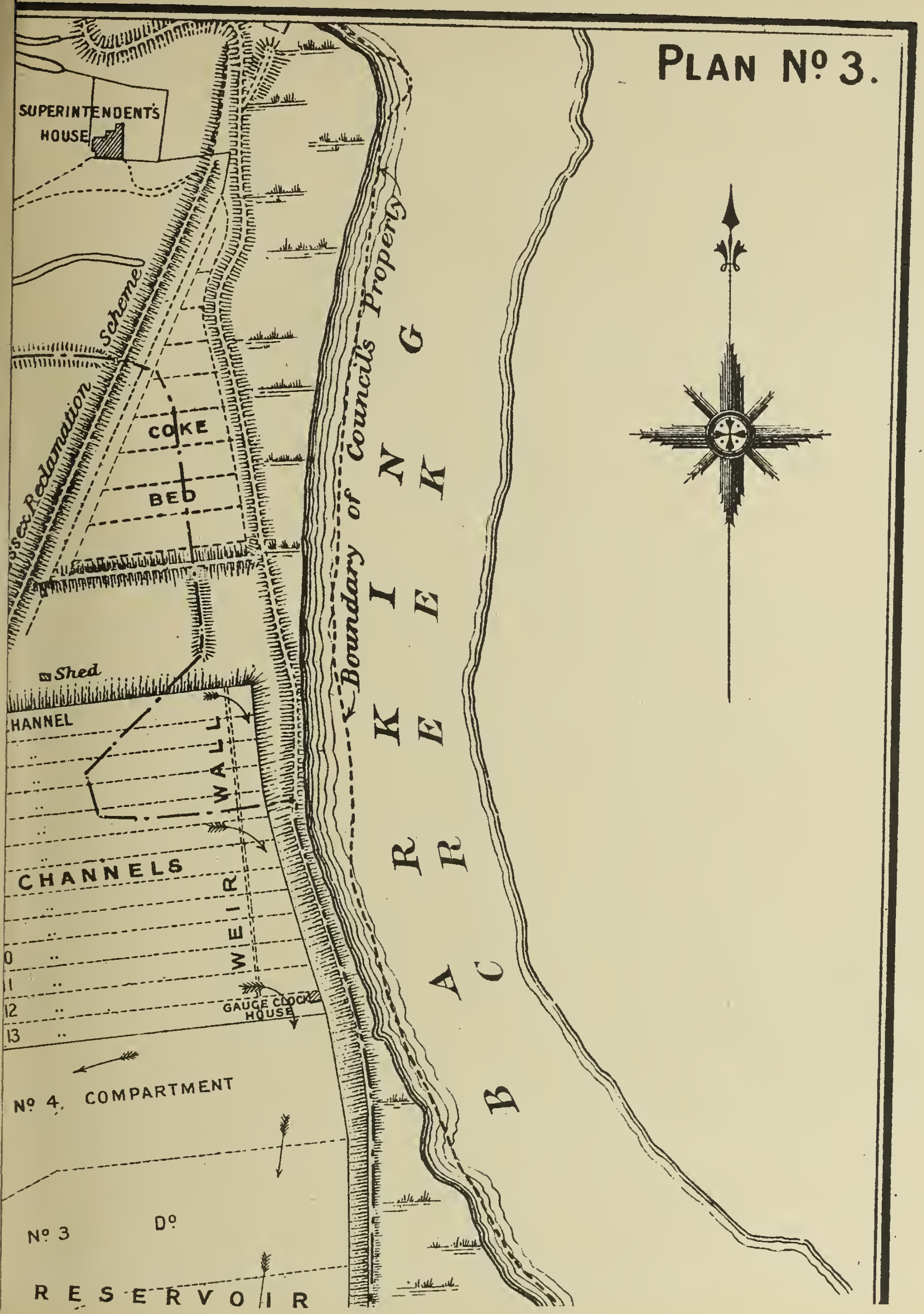
PLAN No. 2



LIGHT BLUE INDICATES APPROXIMATELY AREA WITHIN THE METROPOLIS BELOW A LEVEL OF 17 FT. 6 INS. ABOVE ORDNANCE DATUM.
DARK BLUE „ „ „ „ „ „ „ „ 12 FT. 6 INS. „ „ „

THE DARK BLUE AREA IS ABOUT 10 SQ MILES
THE DARK & LIGHT BLUE AREA „ $21\frac{3}{4}$ „ „

PLAN Nº 3.

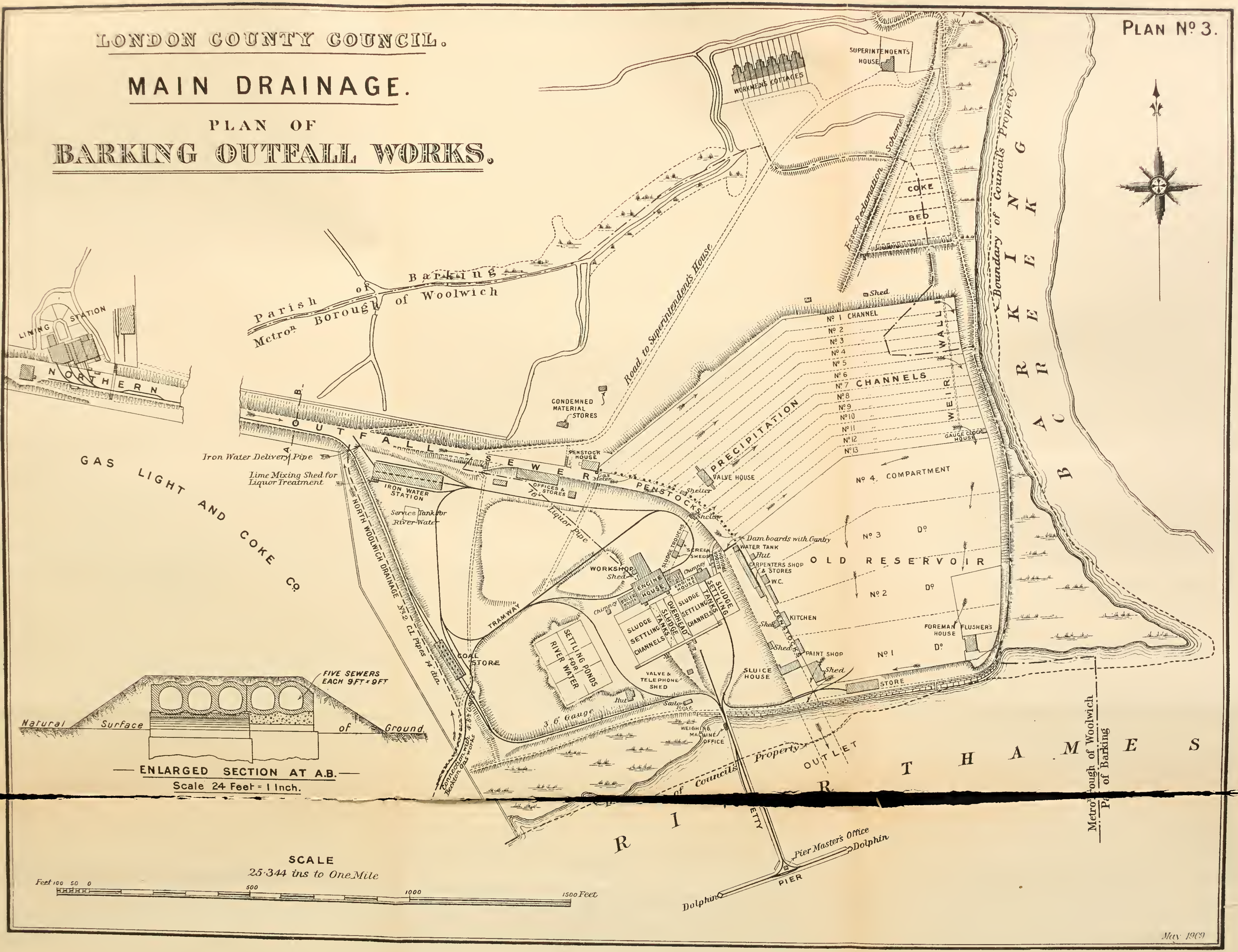

SUPERINTENDENT'S HOUSE
ssex Reclamation Scheme
COKE BED
Shed
HANNEL
WEIR WALL
CHANNELS
0
11
12
13
GAUGE CLOCK HOUSE
Nº 4. COMPARTMENT
Nº 3 Dº
RESERVOIR
Boundary of Councils Property
BARKING CREEK

LONDON COUNTY COUNCIL.

MAIN DRAINAGE.

PLAN OF
BARKING OUTFALL WORKS.

PLAN Nº 3.



ENLARGED SECTION AT A.B.

Scale 24 Feet = 1 Inch.

SCALE

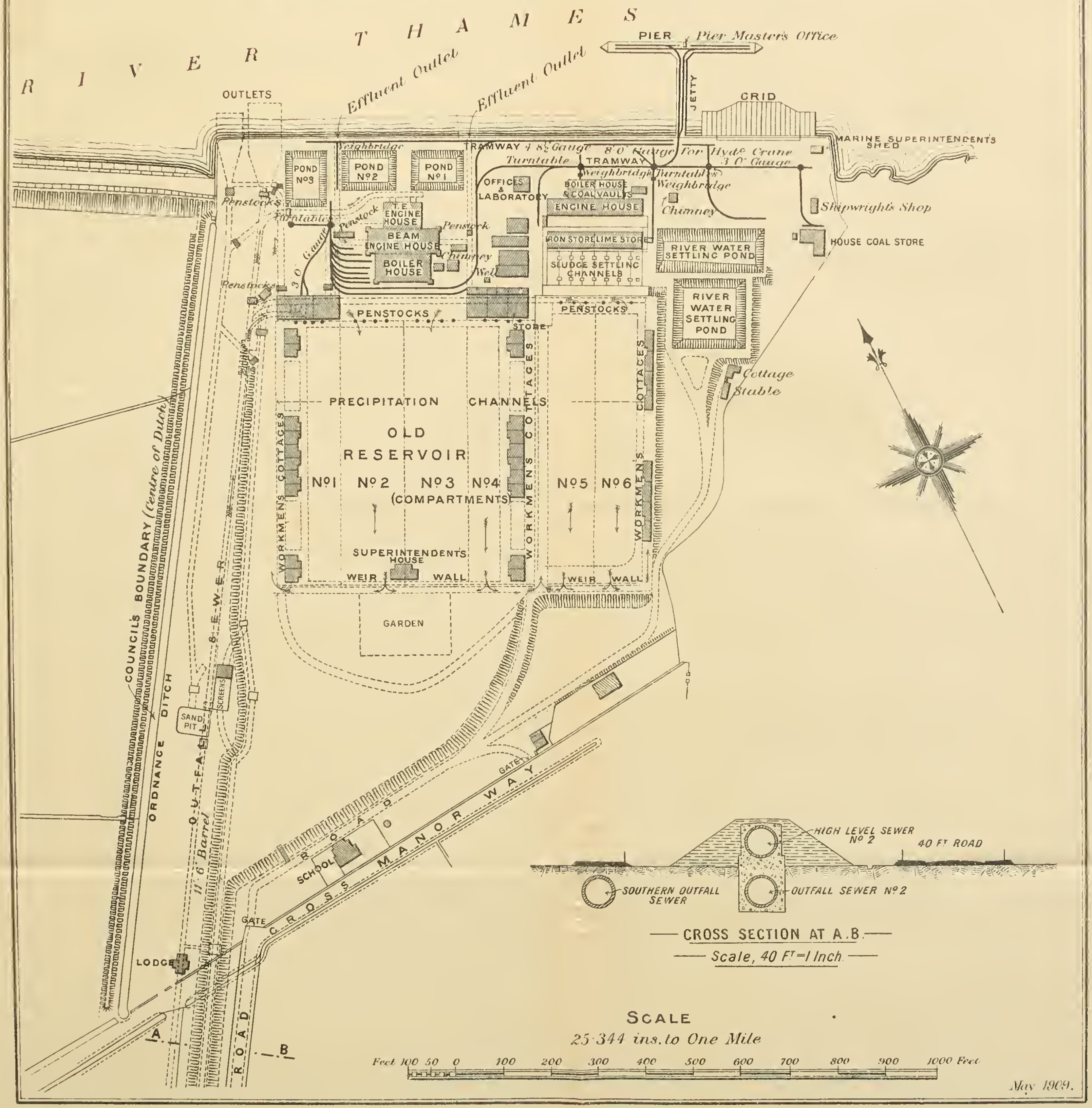
25·344 ins to One Mile

Feet 100 50 0 500 1000 1500 Feet

May 1909

PLAN Nº 4.

LONDON COUNTY COUNCIL
MAIN DRAINAGE.
PLAN OF
CROSSNESS OUTFALL WORKS.



May 1909.